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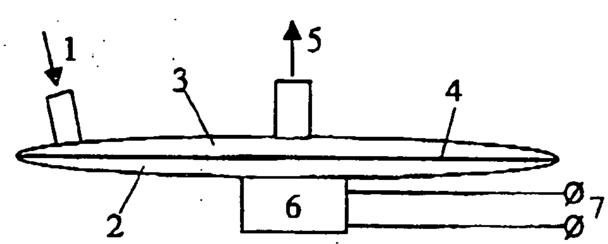
(54) **Microcontroller controlled electric steam generator without separate sensors**

(57) An apparatus with which, by means of electric energy, steam can be generated. The invention makes use of the positive temperature coefficient of the heating resistance of the heating element. Through the use of a microcontroller in the electronics, the current through and the voltage across the heating element can continuously be determined and hence be used for determining and controlling the steam humidity and the pressure of the steam. For this, in principle, no other, separate sensors are needed anymore. Due to the small mass of the through-flow heater, the electronic control can respond rapidly to fluctuations. In view of a predictable through-flow, a spiral-shaped labyrinth is provided. During operation, water flows through the labyrinth. In the first part, the temperature rises from starting temperature to boiling temperature. After that, the temperature of the water up to the outlet of the through-flow heater can be at boiling temperature. Said temperature variation determines the resistance of the heating element. The steam humidity can be adjusted through the system by controlling the pump power. When the flow rate is increased, the steam humidity rises, which is measured by the drop of the resistance of the heating element and can be controlled thereby. Depending on the type of steam generator, an electronically settable excess-pressure valve can be provided on the outlet of the through-flow heater. Upon blocking of the steam outlet, the current supply to the heating element is interrupted. The boiling dry of the through-flow heater leads to direct switching off as well. The electronics are self-testing and switch off the through-flow heater if an error occurs.



Figuur 1

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Description

[0001] The invention relates to an electronic, microcontroller-controlled apparatus whereby, par unit of time, a specific amount of steam is procuced. Depending on the type of the apparatus, this invention enables controlling the pressure and the humidity of the egressing steam.

[0002] The present state of the art regarding the production of steam by means of electricity for, for instance, steam cleaners or saunas is described hereinbelow. By means of mechanical thermostats mounted on the outer side or by temperature sensors connected to an electronic circuit, an electric through-flow heater is approximately brought to a desired temperature. When the desired temperature is reached, the apparatus becomes ready for use. By means of a hand-operated switch or by switching an electronic output, a pump or valve is activated, causing water to be pumped into the through-flow heater. In the first part of the passage through the through-flow heater, the inflowing water is heated up to the boiling point, whereupon the water over the greater part of the passage is converted into steam by means of the energy supplied. When the passing water is not completely evaporated, the non-evaporated water is entrained in the water vapor to the outlet of the steam generator. The water/steam ratio determines the humidity. There are also steam generators consisting of a boiler having a content of from half a liter to a few liters. At the bottom of the boiler, an electric heating element is located. With these steam generators, the energy supply to the heating element is switched off by means of a pressure sensor when the pressure of the boiler exceeds a particular value or when the temperature becomes too high. Most types involve an open communication with the outside air.

[0003] The above-mentioned installations according to the present state of the art have the following drawbacks:

1. Present-day installations and systems in which steam is to be generated involve the use of often rather unwieldy electric through-flow heaters which, in particular if they have been developed to operate at a power supply from a 230V mains connection, are subject to a long warming-up time. This applies to a great extent to the above-mentioned boiler types where all the water must first be brought to the boil.
2. In addition, these steam generators use thermostats mounted on the outer side of the through-flow heater. These thermostats have the drawback that they often respond slowly, due to the mass and the specific heat of the thermostat itself and the heat resistance between the through-flow heater and the thermostat, which largely determine the response time.
3. Further, there are great tolerances in the measuring accuracies and a large hysteresis of these thermostats.
4. In addition, the switching of these thermostats is accompanied by sparking, as a consequence of which the lifetime of these parts is limited.
5. Due to the relatively slow warming-up of the heating elements, layers of scale deposit, which may result in a poor heat transfer to the water. This may also lead to stoppages. In the present steam generators, this effect is retarded through the use of filters in the water supply. By descaling periodically, the lifetime can be prolonged.

[0004] The invention provides a solution to the above-mentioned drawbacks by using a through-flow heater having a small volume and a great electric power density for transferring the required energy to the water in the form of heat.

[0005] The mass of the through-flow heater is small, so that little energy is required for heating up the through-flow heater itself to the required temperature. The resistance in which the electric energy supplied is converted into heat is so arranged that the available heat can be transferred to the water very directly. To obtain a very fast and accurate control, use is made of the positive temperature coefficient of said resistance for determining the temperature. On the basis of the Figures, the principles of the steam generator are elucidated and applications are explained.

[0006] Fig. 1 shows the principle of an electric through-flow heater based on a heating element utilizing a dissipating resistance designed in thick-film technology, enabling the heat generated to be transferred to the rest of the element very directly.

[0007] Fig. 2 shows the block diagram of an electronic circuit with which the principle of temperature measurement and the operation of the control of the steam generator will be explained.

[0008] Fig. 3 shows the setup of a steam generator which draws the water to be evaporated from a pressureless reservoir.

[0009] Fig. 4 shows a circuit wherein the feed to the heating element is switched off in the event of a failure of the microcontroller or the electric control of the heating element is interrupted if an error occurs in said circuit.

[0010] Fig. 5 shows the side of a heating element on which a resistance track is provided between thin insulating and protective layers.

[0011] Fig. 6 shows a spiral-shaped labyrinth in which the water flows while it is being heated up by the underlying heating element.

[0012] Fig. 7 shows the side of a heating element on which a resistance track is provided between thin insulating and protective layers as in Fig. 5, but here, the resistance track is spiral-shaped.

[0013] Fig. 8 shows a spiral-shaped labyrinth in which the water flows while it is being heated up by the under-

lying heating element which, in contrast with Fig. 6, is spiral-shaped.

[0014] Fig. 9 shows graphs of the temperature distribution of the water in the through-flow heater at four different pumping rates as a function of the position in the spiral-shaped labyrinth.

[0015] Fig. 10 shows a graph of the increase in resistance relative to the resistance of a specific heating element at 0°C as a function of the optimal flow (F) at which all the water pumped in is precisely entirely evaporated at the outlet of the through-flow heater.

[0016] To realize a steam generator in which an electric heating track can be used as temperature sensor, it is necessary that a lowest possible thermal resistance and thermal capacity be present between the heating track and the water to be heated, so that a short response time is present. In Fig. 1, a heating element (2) on the basis of thick-film technology is used. With this type of heating elements, it is presently possible to dissipate powers up to about 60 watt per cm^2.

[0017] By a thin electric insulator, the thick-film resistance (23) (Fig. 5) is thermally and mechanically coupled to a slightly spherical support (2) (Fig. 1), which may be of stainless steel (SS) design. The thickness of the SS is about 1 mm. The electric connection to the heating element is effected by means of an adapter (6) (Fig. 1), which establishes the connection to the ends of the heating track (24) (Fig. 5) by means of spring contacts. The supply voltage is connected to the terminals (7) (Fig. 1). The through-flow heater (Fig. 1) is created by coupling a spherical cover (3), provided with a water inlet (1) and a steam outlet (5), to the heating element, the lower spherical segment (2), by means of a welded joint (4). Depending on the application, said spherical segments (2+3) can also be joined together by a circular V-shaped clamp having a layer of elastic plastic or rubber suitable for higher temperatures. Due to the fast heating up of the SS, calcium layers which may be present on the water side break up into small pieces. This breaking up is caused by the formation of mechanical stresses between the SS and the calcium deposit, in that the heating element expands sooner and faster by heating up. This renders the use of a water inflow filter unnecessary.

[0018] For a better operation of the through-flow heater shown in Fig. 1, a spiral-shaped object of a high melting point and a high thermal resistance and a low specific heat can be fitted in this space, which object provides that the water supplied at (1) (see also 26 (Fig. 6) or 28 (Fig. 8)) flows along the outer side of this spiral in a spiral-shaped labyrinth towards the center and can leave the outlet (5) (see also 27 (Fig. 6) or 29 (Fig. 8)) in the form of steam and together with any unevaporated water. An advantage of the use of a spiral is that the through-flow heater can also be used at an angle of inclination of more than 45° without there being formed unduly hot spots on the heating element. This is due to the spiral which provides that the water cannot drop back to one side of the through-flow heater. The spiral-shaped labyrinth (25) (Fig. 6) mentioned may form an integral part of a plastic cover for forming the through-flow heater (Fig. 1) together with the heating element (2). In Fig. 2, the current through the heating element (15) is measured by converting the current through the low-ohmic measuring resistance (14) into a voltage. This measured AC voltage is fed to the electronic circuit (12) which amplifies the measured voltage slightly and subsequently converts it into a DC voltage which is proportional to the AC current through the measuring resistance (14). At a constant supply voltage (11), the current through measuring resistance (14) is influenced by the temperature variation over the heating track (11) of the heating element (15), which is the result of the positive temperature coefficient of the resistance material of the heating track.

[0019] Calculations demonstrate that with a 1500 watt heating element, a voltage change of about 5 millivolt per degree Kelvin can be created across the measuring resistance (14). As the measuring resistance (14) has a resistance value which is smaller than the track resistance of the heating element (15) by a factor of 100-200, here, only a measuring resistance suitable for a low power is needed. Since in practice, the supply voltage (11) may vary considerably, there is provided an electronic and software-mediated error correction. To enable carrying out said correction in the microcontroller (8), a DC voltage is presented co the microcontroller (8) via the electronic circuit (9), which DC voltage is proportional to the prevailing voltage on the heating element. Circuit (10) provides for the feed of the electronic circuits of said control. By means of the potentiometer, (13) (or by means of a value stored in the microcontroller), driven by a reference voltage (V_{ref}), the desired temperature can be set and, by the control, be maintained. By means of a user interface consisting of a few keys and a display, which are connected to the microcontroller (not shown), specific settings (such as pressure, steam humidity and flow) can be effected and it can be checked, via the display, what is the status of the apparatus.

[0020] When the desired calculated temperature starts to fall undesirably, this points to the supply of too much water. However, the microcontroller (8) can maintain the temperature by controlling the pump capacity to a lower value. Due to the above-mentioned control properties of the invention, the system recognizes within a few tenths of a second that the water supply stagnates due to a defective pump or pump control, or simply because the water has run out. Upon the consequently detected rise of the temperature, the microcontroller will stop the current supply to the heating element (15) by means of triac Trl. Hence, this provides a very fast boiling-dry protection. In the control system described so far, the temperature cannot be measured after switching off of the heating element (15). By reheating after a short interval, while the pump remains driven, it can be detected whether the temperature has dropped. If this is

not the case, the intervals will have to be prolonged. It is always possible, depending on the application, to couple an external temperature sensor to the through-flow heater, whereby the microcontroller can measure the temperature variation (with a longer response time) without necessitating energy supply to the heating track. By means of, for instance, an optic triac Tr2 (preferably with zero-passage detection against line interference), the microcontroller (8) can switch the water pump (16) on and off in fast alternation to control the water flow at the inlet (1) (Fig. 1). By means of the software, triac Tr1 (and also triac Tr2) is controlled by the microcontroller (8) in such a manner that after a control interruption, a positive half period of the sine voltage (0-180°) is succeeded by a negative half period (180-360°) and vice versa, so that line interference is prevented. During said control of the supplied electric power to the heating element, the measured voltage on the measuring resistance (14) will not be an uninterrupted sine shape. However, as circuit (12) uses the amplitude of the voltage, the temperature measurement can be continued normally, with the understanding that due to the time constant for smoothing the signal from the rectifier of circuit (12), this output voltage will decrease, which will have to be corrected in the software. Accordingly, in the software, allowance is made for a measuring error caused by the change of the measured mains voltage, through a changed load, which is transmitted by circuit (9) to the microcontroller (8). Fig. 3 schematically represents a possible application of the invention, which could be used in a steam cleaner, sauna or any other apparatus requiring a stable supply of steam for a proper operation. The apparatus provides a pump (18) controlled by the electronics (21) and capable of building up sufficient pressure for supplying water also if the steam pressure rises, the through-flow heater (19) and, when this is desired in the apparatus, an electronically settable excess pressure valve (20), whereby it is achieved that through a further rise of temperature, the pressure in the through-flow heater (19) will increase to a value equal to the set pressure value of the excess pressure valve, as a result of which the excess pressure valve will open and steam will egress at an increased pressure. Because of the distribution in the resistance values of the different heating elements produced, this invention provides a system for automatically performing a calibration of the temperature during the operative mode of the apparatus, for instance each time at the startup. For this, use is made of the boiling point of water under atmospheric conditions. To this end, the excess pressure valve (20), if present in the apparatus, is fully opened electronically.

[0021] The pump (18) is set in operation by the electronics (21) for so long that the through-flow heater of Fig. 1 is filled with water for more than 50%, so that the hollow heating element is entirely filled. After that, electric energy is transmitted at maximal power to the through-flow heater (19). By the manner of temperature measuring described, it will be detected that the temperature of the heating element (2) (Fig. 1) will rise.

[0022] This rising will continue until the water in the through-flow heater reaches its boiling point. After that, the temperature of the water will remain stable (100°C) until all the water has evaporated. The boiling point may then be slightly higher because of the pressure rise due to the resistance experienced by the steam through the passage through the outlet (5) and the hoses connected thereto. The temperature of the heating track (23) (Fig. 5) on the heating element (2) will be slightly higher due to the heat resistance between the heating track and the water to be evaporated. After that, calibration can be effected very precisely by adjusting back the power to the heating element so far that said temperature difference becomes minimal and the water is still boiling. The derived measuring value is stored in a nonvolatile memory and can thereafter be used as reference point to enable measuring other temperatures as well through calculation, since the properties of the heating element are known after that. Because said calibration is also performed during the testing of the apparatus in the factory, a temperature determination can already be performed within one second after the heating element has been switched on. The result of this measurement is a good approximation for the water temperature in the reservoir (17) (Fig. 3). Because the energy required for heating 1 gram of water from 20°C to 100°C is only 334 Joule (~12.9%), while said heating and evaporating (at 100°C) of this quantity requires 2590 Joule of energy, an error of 10°C in the determination of water temperature in the reservoir (17) (Fig. 3) would lead to an error in terms of percentage, in the determination of the amount of water which will evaporate upon supply of a given amount of energy, of maximally

$$\frac{334[J]}{2590[J]} * \frac{10[°C]}{(100\text{-}20)[°C]} * 100\%=1.6\%.$$

[0023] Due to this calibration, during the use of the electronically controlled excess pressure valve, or during the intentional or unintentional closing of the steam outlet, it is possible to calculate the pressure in the through-flow heater (19) (Fig. 3). When the pressure increases, the boiling point will also be higher. At a boiling point of 100°C, the absolute pressure is $101.3.10^3$ Pa. When for instance the maximal pressure may be three times as high (304.10^3 Pa), the new boiling temperature may maximally be 133.8°C. Depending on the rate at which the temperature rises, it can be determined whether the absence of water is involved or whether an unduly high pressure is involved. In the latter case, the electronics will be able to guarantee the safety by switching off the current to the heating element by means of triac Tr1.

[0024] In principle, said temperature measurement/pressure determination is also possible with conventional heating elements in a boiler (see present state of the

art), in respect of which allowance should be made for the longer response times and, accordingly, the possible occurrence of dangerous situations. As mentioned, with said through-flow heater and electronics, it is possible to generate steam of a predetermined mass per unit of time, a predetermined humidity and a predetermined pressure. During the control of said quantities, the pump (16 (Fig. 2) and 18 (Fig. 3)) will pump a specific amount of water per minute into the through-flow heater. This water will be passed via the spiral-shaped labyrinth (Figs. 6 and 8) to the center of the heating element. At a specific set power to the heating element, it is calculated in the microcontroller how much water can, at a specific pressure, be converted into steam per minute. The desired pressure is set by the electronic reducing valve (if present in the apparatus). Figs. 5 and 7 show two embodiments of the thick-film resistances on the heating element. The advantage of the heating element in Figs. 7 and 8, because the heating track co-extends precisely under the spiral-shaped labyrinth, is that the temperature variation in the water from the inlet (28) to the outlet (29) rises equally with the temperature of the resistance track, so that this track has no great temperature transitions, while in Figs. 5 and 6, the resistance track (23) extends along spots where the temperature of the water may differ substantially. As a result, the track of the heating element of Fig. 7 has a longer lifetime. If the pump (16 (Fig. 2) and 18 (Fig. 3)) at a given power pumps too little water into the through-flow heater, all the water will already be converted into steam before reaching the outlet (see 5 (Fig. 1), 27 (Fig. 6) and 29 (Fig. 8)). Because the heat transfer to steam is much poorer than to water, the temperature of the heating element will rise substantially at those locations. The resistance of the heating track is in fact determined by three temperature areas (Fig. 9):

1. The first part of the spiral labyrinth, where the water is heated from the input temperature TIN to the boiling point.
2. The portion where the energy which is available at that location is used for evaporating the boiling water.
3. The final part of the spiral labyrinth, where the temperature of the heating element may be considerably higher than the boiling temperature at the prevailing pressure.

[0025] In Fig. 9, the variation of the temperature is represented graphically. Graph B is the graph where the amount of water pumped into the through-flow heater (Fig. 1) has precisely evaporated when reaching the outlet (5). At an inflow temperature of 20°C of the water at the inlet of the through-flow heater (1) and a boiling point of 100°C, the heating up to this boiling point takes 12.9% of the available power. This power is used in the first 13% of the passage through the spiral labyrinth. In graph A in Fig. 9, the flow is lower by a factor of 2, so that the path in the labyrinth in which the water boils is reduced to half the path in graph B.

[0026] As a result, just after half the path (about 56% of the path through the spiral), all the water has evaporated. Consequently, the temperature in this area rises substantially. Graphs C and D respectively show a flow which is two and about five times as great as in graph B. In graphs B through D, the steam humidity becomes greater and greater. In graph D, for instance, only half of the water has evaporated. The purpose of graph E is to demonstrate that at a higher pressure, more time is needed for bringing the water to the higher boiling point, in which case the water has to flow further into the labyrinth to absorb the required energy. However, the flat portion (where the water boils and is converted into steam) of graph E is shorter than the flat portion in graph A, because the evaporation value at a higher pressure is lower.

[0027] The resistance of the heating element is the result of the sum of the resistances of the three temperature areas mentioned. Fig. 10 shows how the resistance, relative to the resistance at 0°C, represented by the vertical axis, depends on the flow and the prevailing pressure (at atmospheric pressure or during the use of an electronically controlled excess pressure valve (20) (Fig. 3)), at a constant power. When a heating element according to Figs. 7 and 8 is started from, the heating track at a given position is at approximately the same temperature as the water flowing past on the other side of the heating element. For any pressure, a graph as shown in Fig. 10 can be derived. On the horizontal axis, 'optimal flow (F)' is understood to mean the through-flow at which all the supplied water, during its complete course through the spiral labyrinth, has precisely evaporated completely. The bending point in the graph of Fig. 10, at F=1, is a reference point for the control. In the case of an open connection (atmospheric pressure) with the outside air, the resistance calculated by the microcontroller can be related to the steam humidity of 0% at a boiling point associated with the prevailing atmospheric pressure. With this method, by determining the resistance at a 'bend', at the prevailing pressure, a fast method for determining the above-mentioned optimal flow (F) is available. From the determination of this bending point in the graph, the microcontroller can increase the steam humidity by increasing the pump power, or by reducing the power to the heating element. When the power is reduced, less water can be converted into steam, as a result of which the control is no longer at a point of optimal flow of a graph. For instance a halving of the supplied power to the heating element will shift the working point of the control to the point 2x the optimal flow (F). Deviations relative to the theory here described in a specific embodiment of an apparatus, caused by the differences in resistance occurring in the hoses and accessories connected to the outlet (5) (Fig. 1), are corrected by software per type of apparatus by means of measurements of the properties of the relevant type of

apparatus.

[0028] Because in Fig. 2, the triac Tr1 has a particular chance of becoming defective, so that it would constantly remain conductive, normally an external safety thermostat is needed which switches off the voltage when a maximum temperature is being exceeded. In apparatuses utilizing the invention described herein and an extension of the electronics according to Fig. 4 described hereinbelow, the provision of a safety thermostat is not necessary.

[0029] Relay RY1 (Fig. 4) has a make-contact whereby, in cases of failure, the heating element (15) (Fig. 2) can be switched off.

[0030] The relay will de-energize if the program in the microcontroller is not or no longer properly performed. In that case, the lower terminal pin of capacitor C1 will no longer be provided with a block-shaped signal. Accordingly, transistor T3 will start to block, so that C2 will start to charge itself to such an extent that the base current from transistor T1 becomes so low that this transistor starts to block as well. As a result, the relay RY1 will de-energize and contact ryl is opened.

[0031] Thus, the voltage provision to the heating element is broken. The proper operation of the safety circuit of Fig. 4 is tested very regularly by the microcontroller. The voltages on the collectors of all transistors are checked by the microcontroller interface (22) for a variety of combinations of the two control signals from the microcontroller interface to the transistors T2 and T3. Any deviation found will lead to the switching off of relay RY1 and triac Tr1. In addition, as already mentioned, the total system is so designed that also at a particular limiting rising pressure, at an unduly high temperature (hence also in the case of boiling dry) it will interrupt the voltage provision to the heating element very fast. Each time after switching off, the proper operation of triac Trl is tested by checking whether no current passes through the measuring resistance (14) anymore.

[0032] Through the use of a microcontroller and suitable software, it has become possible to generate steam in a controlled and integrally safe manner, in the abovementioned manner.

Claims

1. A microcontroller-controlled steam generator provided with an electric heating element, **characterized in that** for controlling the properties of the steam, use is made of the measured current through the heating element and the measured voltage across the heating element, as a result of which the use of separate sensors is not necessary.

2. An apparatus according to claim 1, **characterized in that** the apparatus is designed so that the influence on the measuring result, caused by fluctuations in the voltage, is compensated by the program performed in the microcontroller, by using the voltage measured across the heating element.

3. An apparatus according to one or more of the above claims, **characterized in that** the apparatus is designed so that measuring errors caused by mutual differences in the resistance of heating elements produced can be prevented by causing a short, automatic calibration to be performed periodically, wherein water under atmospheric pressure is brought to the boil in the through-flow heater and the current through the heating element is measured.

4. An apparatus according to one or more of the above claims, **characterized in that** the temperature of the inflowing water is determined in the best possible approximation by filling the through-flow heater with a sufficient quantity of water and immediately performing a measurement when the voltage across the heating element is switched on.

5. An apparatus according to one or more of the above claims, **characterized by** a through-flow heater having a small mass and low specific heat and a high power per unit area and a relatively small content, to realize a control system which can respond rapidly to fluctuations, so that the set, desired values can efficiently be maintained.

6. An apparatus according to one or more of the above claims, **characterized in that** via a spiral-shaped or differently shaped labyrinth, the water is passed from the water inlet to the steam outlet, so that the water and the steam flow through the through-flow heater via a defined route, so that at a specific power and flow, the temperature at any point can be theoretically derived, said temperature variation determining the total resistance of the heating track of the through-flow heater.

7. An apparatus according to one or more of the above claims, **characterized in that** the apparatus is designed so that during the performance of the measurements by the microcontroller the temperature of the water flowing past at any position can be determined.

8. An apparatus according to one or more of the above claims, **characterized in that** the microcontroller is designed for determining at a given power supplied, by changing the flow, a point at which all the water, after the passage through the through-flow heater, has precisely been converted into steam, referred to as the optimal flow (F), which is detected by a stronger decrease of the current than normal, due to the rise of the temperature in the area of the steam outlet of the through-flow heater, when the

flow is caused to decrease further.

9. An apparatus according to one or more of the above claims, **characterized in that** the microcontroller is designed for influencing the power supplied to the through-flow heater, at a specific unchanging water through-flow, enabling the steam humidity to be set at a desired value.

10. An apparatus according to one or more of the above claims, **characterized in that** the microcontroller is designed for influencing the pump capacity, at a specific unchanging electric power, enabling the steam humidity to be set at a desired value.

11. An apparatus according to one or more of the above claims **characterized in that** through the use of a labyrinth in the through-flow heater, the steam generator can be used at angles of inclination up to about 45°

12. An apparatus according to one or more of the above claims, **characterized by** means which in the case of dry boiling or undue heeling over of the through-flow heater detect the resistance which rapidly increases due to the rapidly increasing temperature, whereupon the electronics directly provide for the switching off of the voltage of the heating element.

13. An apparatus according to one or more of the above claims **characterized in that** upon the closing of the steam outlet. the microcontroller signals the resulting increase of the pressure and the consequent rise of the resistance of the heating element, whereupon the current supply to the heating element is switched off.

14. An apparatus according to one or more of the above claims. **characterized in that** the heating track is substantially identical in shape to the labyrinth, so that no great differences in temperature and resulting mechanical stresses are caused in the heating track

15. An apparatus according to one or more of the above claims. **characterized in that** heating elements on the basis of thick-film technology are used, so that the application of a supply filter is not necessary, since due to the fast heating up of the SS, and the fast local expansion of the SS, the calcium layers which may be present on the water side break up into small pieces, said small pieces being entrained by the steam to the outside.

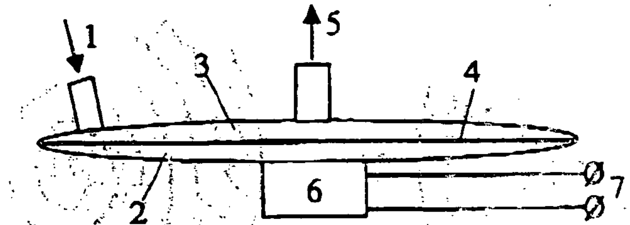
16. An apparatus according to one or more of the above claims, **characterized in that** during normal functioning, the electronics monitor the pressure and/or temperature, so that for guaranteeing the safety, no separate pressure sensor or over-temperature sensor is needed, while in the event of a failure in the electronics themselves, an error in the program run in the microcontroller will be detected by the rest of the electronics, while an error in the last-mentioned part of the electronics will be detected in that the microcontroller is programmed to perform periodical tests which will lead to the switching off of the current supply to the through-flow heater.

17. An electric circuit arranged for use in an apparatus according to any one of the preceding claims.

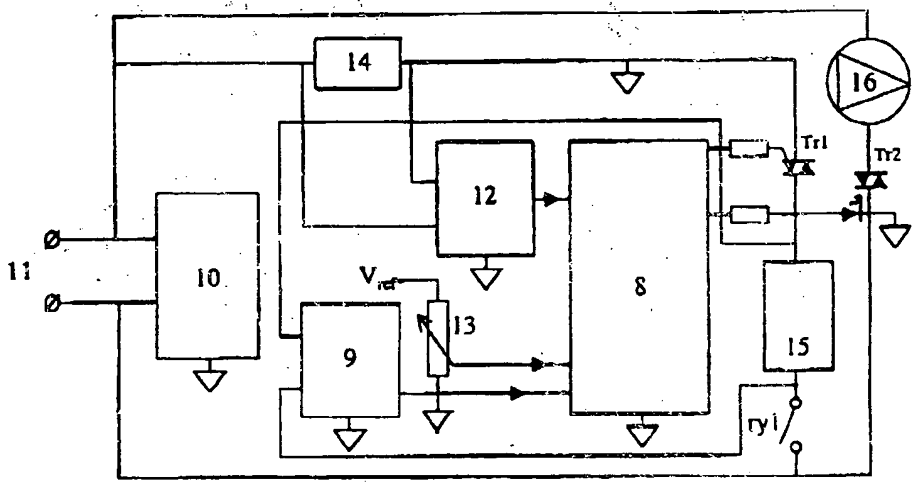
18. A microcontroller programmed for use in an apparatus according to any one of the preceding claims.

19. A through-flow heater for use in an apparatus according to any one of the preceding claims, **characterized by** two spherical segments, mounted one onto the other, having a water inlet and a steam outlet and a heating element designed as a resistance formed in thick-film technology.

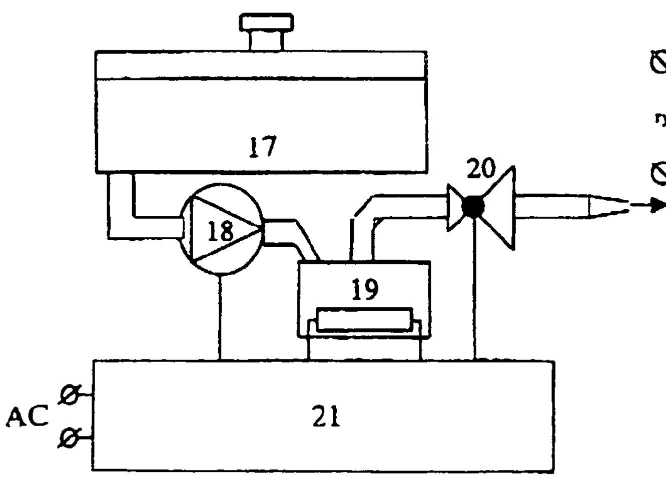
20. A through-flow heater for use in an apparatus according to any one of claims 1-18 or according to claim 19, **characterized by** an approximately spiral-shaped labyrinth enclosed between the spherical segments.



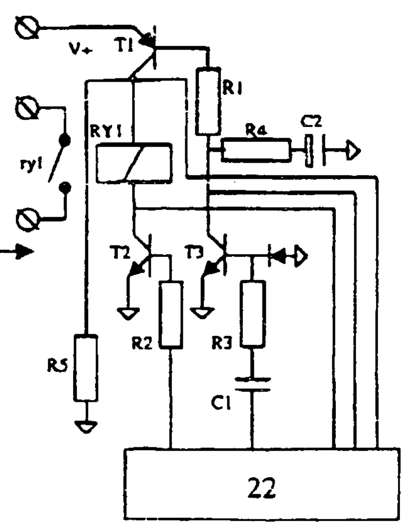
Figuur 1



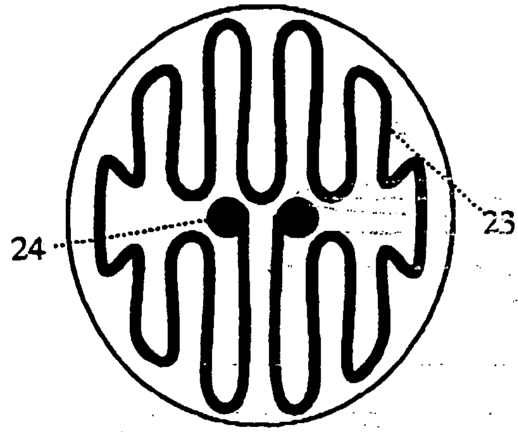
Figuur 2



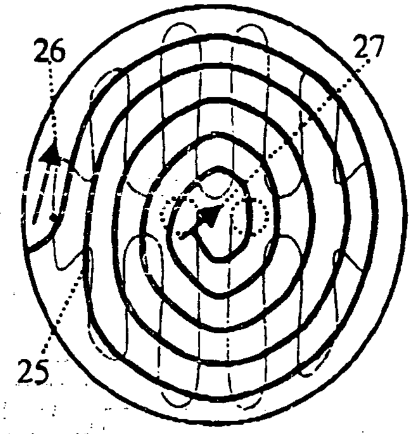
Figuur 3



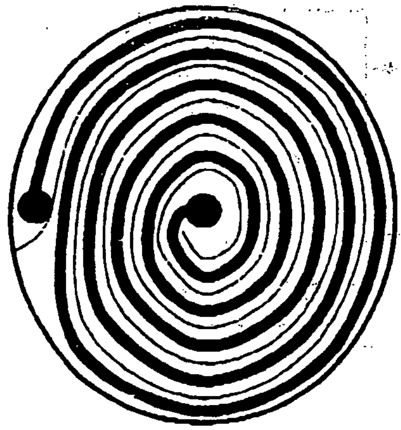
Figuur 4



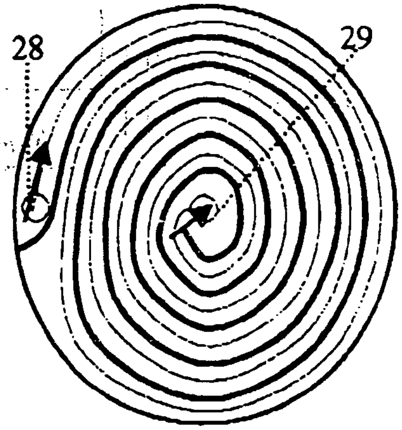
Figuur 5



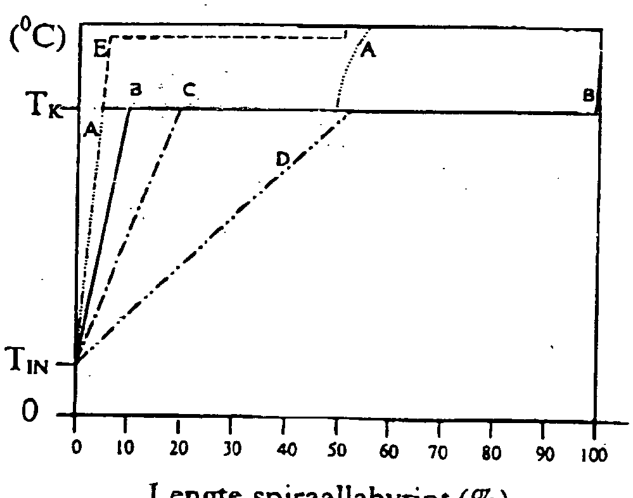
Figuur 6



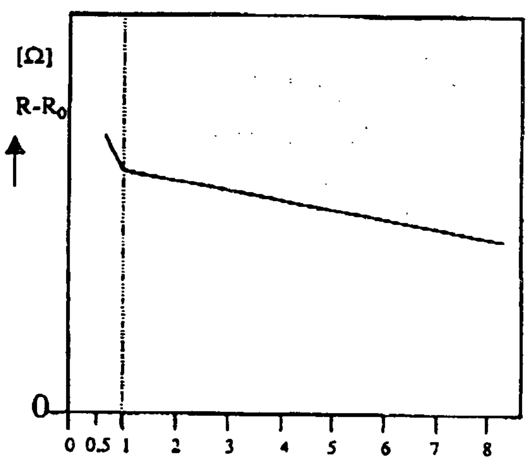
Figuur 7



Figuur 8



Figuur 9



figuur 10

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 20 4312

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	DE 195 09 772 C (DRAEGERWERK AG) 11 July 1996 (1996-07-11) * column 2, line 24 - column 3, line 26; figures *	1	F22B1/28
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 March 2000	Van Gheel, J

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